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Improving learners' attitudes in physical sciences through formative assessment: An intervention study

Halalisani Mngomezulu [1*], Sam Ramaila [1], Lydia Mavuru [1]

[1] Department of Mathematics, Science and Technology Education, Faculty of Education, University of Johannesburg, Johannesburg, SOUTH AFRICA

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Abstract

This study examined the impact of formative assessment practices on grade 10 learners' attitudes toward physical sciences, using self-determination theory (SDT) as a guiding theoretical framework. A quasi-experimental design with a mixed-methods approach was employed to provide a comprehensive understanding of the intervention's effects. The sample consisted of 175 learners from five secondary schools in KwaZulu-Natal, divided into an experimental group (n = 118) and a control group (n = 57). The experimental group was exposed to a structured formative assessment intervention aimed at promoting autonomy, competence, and relatedness, core tenets of SDT, while the control group continued with conventional instructional methods. Data were collected through pre- and post-intervention attitude questionnaires to assess shifts in learners' perceptions of physical sciences. Quantitative data were analyzed using descriptive and inferential statistics. The results revealed a significant improvement in attitudes among learners in the experimental group, while the control group showed minimal change. These findings suggest that formative assessment practices, when aligned with SDT, can enhance learner motivation, engagement, and overall attitude toward learning physical sciences.

Keywords: formative assessment, intervention, physical sciences, grade 10

INTRODUCTION

The teaching and learning of physical sciences continue to face challenges globally, particularly in terms of learners' engagement, motivation, and academic achievement. Despite the subject's importance in driving innovation, technological development, and scientific literacy, many learners perceive physical sciences as difficult and abstract, often resulting in low achievement and negative attitudes (Assem et al., 2023). Positive attitudes are critical as they can influence learners' willingness to participate, persist, and perform in the physical sciences subject (Mngomezulu & Ramaila, 2024).

In response to these challenges, the study by Mngomezulu et al. (2022) revealed that teachers and researchers have increasingly turned their attention to the use of formative assessment as a pedagogical strategy aimed at enhancing the teaching and learning process. Formative assessment refers to a range of evaluative practices used during the learning process to provide immediate feedback, identify learning gaps, and inform teaching and learning (Heritage, 2021). Unlike summative assessments, which evaluate learners' learning at the end of an instructional period (Ismail et al., 2022), formative assessments are continuous and diagnostic in nature, aiming to support learning rather than just measure it.

Recent research by Yan et al. (2021) suggests that well-designed formative assessment interventions can not only boost academic achievement but also positively influence learners' attitudes towards learning, particularly in subjects perceived as difficult, such as physical sciences and other STEM subjects. Through the active involvement of learners in their own learning process, formative assessments can promote greater self-efficacy, interest, and a sense of ownership over learning outcomes. Moreover, the study by Molin et al. (2021) indicates that timely feedback can help learners better understand scientific concepts, reduce anxiety, and improve performance.

✉ makwempe@gmail.com **(*Correspondence)** ✉ samr@uj.ac.za ✉ lydiam@uj.ac.za

Contribution to the literature

- The study extends the application of Ryan and Deci's (2000) self-determination theory (SDT) by demonstrating how formative assessment practices can be intentionally designed to support learners' autonomy, competence, and relatedness in the context of physical sciences. This adds to the theoretical literature by linking SDT more concretely with instructional strategies in secondary schools' science education.
- By employing a quasi-experimental mixed-methods design, the study provides robust empirical evidence that formative assessment interventions significantly improve learners' attitudes toward physical sciences. This contributes to the growing body of literature that supports formative assessment not just as a tool for academic achievement but also as a mechanism for enhancing learner motivation and engagement.
- The study provides practical, classroom-based evidence on how structured formative assessment can be implemented effectively in secondary physical sciences education. By showing measurable improvements in learners' attitudes, it bridges the gap between theory and practice, offering teachers and curriculum designers actionable strategies to enhance learner motivation and engagement in science subjects.

This study investigates the effectiveness of a formative assessment intervention in improving learners' attitudes in physical sciences. Specifically, it explores how the integration of regular formative assessment practices in classroom practice impacts learners' perceptions of the subject, which is physical sciences.

Research question guided this empirical study:

How does the integration of formative assessment intervention influence learners' attitudes toward learning physical sciences?

LITERATURE REVIEW

Learners' Attitudes Towards Physical Sciences

Learners' attitudes toward physical sciences have been the focus of extensive educational research due to their significant influence on academic performance, subject choice, and long-term career interests in STEM fields, as eloquently alluded to by Tytler and Ferguson (2023). Attitude in this context refers to a learner's predisposition to respond favorably or unfavorably to physical science, encompassing factors such as interest, enjoyment, motivation, and perceived relevance of the subject.

A number of studies, including Wong et al. (2023), have consistently shown that learners often perceive physical sciences [physics] as difficult, abstract, and less engaging compared to other science subjects like life sciences [biology]. This perception contributes to a generally less favorable attitude toward the subject [physical sciences], which can lead to poor performance and reduced enrolment in physical sciences-related courses post-matric.

Teaching Methods

Teaching methods have a critical impact on shaping learners' attitudes and beliefs towards science teaching and learning. The study by Vilakazi et al. (2024) revealed that learners respond more positively when science is taught using inquiry-based, practical, and learner-centered approaches, including code-switching. In agreement, Towns-Belton (2022) posit that traditional teacher-driven methods can reinforce negative perceptions by making STEM subjects appear rigid and disconnected from real-life experiences. The role of the teacher is also significant; learners are more likely to develop positive attitudes when their teachers are enthusiastic, knowledgeable, and able to relate content to everyday contexts.

Socio-Economic and Cultural Factors

These factors further influence learners' attitudes. In under-resourced schools, where access to laboratories, equipment, and qualified science teachers is limited, learners often lack exposure to meaningful science experiences, which hampers both their interest and confidence (Anto et al., 2023). Similarly, Pierszalowski et al. (2021) found that learners from communities where science is not seen as a viable career path due to economic constraints or lack of role models may develop ambivalent or negative attitudes toward the subject. Curriculum design and assessment practices can either support or hinder positive attitudes. When the curriculum is overly theoretical and focused on high-stakes testing or be it exam-driven, learners may become anxious or disengaged. However, when science education includes real-world applications, group work, and the use of technology such as PhET simulations or virtual labs, learners can have greater interest and motivation (Mashami et al., 2023).

There is strong evidence to suggest a positive correlation between learners' attitudes and their academic achievement in physical sciences. Zenda (2021) encapsulate that learners who enjoy and value the physical sciences tend to perform better and are more likely to pursue further studies in scientific fields or careers that have a scientific focus. Moreover, the study by Prastikawati et al. (2024) revealed that several interventions have been proposed and implemented to improve attitudes, including science outreach programs, mentorship opportunities, integration of technology, and reforms in teacher training to promote more effective pedagogical approaches. However, despite progress, gaps in the literature remain. For example, much of the existing research focuses on academic achievement more than attitudes in the physical sciences, and there is a need for more longitudinal studies that track changes in learners' attitudes over time (Turetsky et al., 2021). Also, more research is needed in diverse cultural and regional contexts, particularly in rural and developing areas, to better understand localized challenges and inform targeted strategies so as to improve learners' attitudes in physical sciences.

Learners' attitudes toward physical sciences are influenced by a complex interplay of personal, instructional, and contextual factors (Pongsophon, 2024). Addressing negative perceptions and promoting positive attitudes is essential for improving learning outcomes and increasing participation in science-related careers. This calls for coordinated efforts in curriculum development, teacher education, and school policy to create engaging, inclusive, and supportive science learning environments.

THEORETICAL FRAMEWORK

SDT, developed by Ryan and Deci (2000), is a prominent psychological framework that explains human motivation, especially in educational settings. SDT emphasizes the importance of intrinsic motivation, the drive to engage in activities out of genuine interest and personal value rather than external rewards or pressures. This theory is highly relevant to this study on enhancing learners' attitudes in physical sciences through formative assessment because it provides insight into how assessment intervention strategies can foster a supportive learning environment that nurtures intrinsic motivation, thereby improving learners' attitudes toward the subject, which is physical sciences.

Core Components of Self-Determination Theory

SDT posits that attitudes and motivation quality depend on the satisfaction of three fundamental psychological needs (**Figure 1**):

1. **Autonomy:** The need to feel in control of own learning and decisions.
2. **Competence:** The need to feel effective and capable of succeeding in tasks.
3. **Relatedness:** The need to feel connected to others and supported socially.

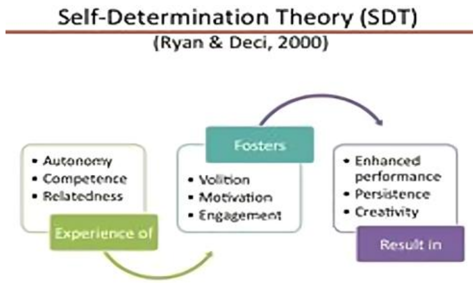

Figure 1. SDT (Ryan & Deci, 2000)

When these needs are met, learners experience higher intrinsic motivation, engagement, and positive attitudes toward learning.

How SDT Underpins This Empirical Study?

This intervention study used formative assessment as a mechanism to satisfy these psychological needs in the context of physical sciences teaching and learning:

Supporting autonomy

Formative assessment practices such as self-assessment, choice in tasks, and opportunities to reflect on learning encourage learners to take ownership of their learning process. Through giving learners control over their pace and methods of learning, formative assessment nurtures autonomy, which, according to SDT, increases intrinsic motivation and positive attitudes.

Enhancing competence

One of the critical roles of formative assessment is providing timely, specific, and constructive feedback. This feedback helps learners identify strengths and areas for improvement, which boosts their sense of competence. When learners see their progress clearly through formative feedback, they develop confidence in mastering physical sciences concepts, leading to more favorable attitudes toward the subject.

Fostering relatedness

Formative assessment often involves social interaction, such as peer feedback or collaborative discussions, which helps learners feel supported and connected to teachers and classmates. This social support satisfies the need for relatedness, reinforcing motivation and positive emotional engagement.

Relevance to Learners' Attitudes in Physical Sciences

Attitudes toward physical sciences are shaped by learners' motivational experiences in the classroom. When learners feel autonomous, competent, and connected, they are more likely to value the subject and engage with it positively. Conversely, Bragg (2024) is of the view that traditional assessment methods that emphasize high-stakes summative testing can undermine motivation by fostering anxiety, fear of failure, and feelings of incompetence.

The study's formative assessment intervention, grounded in SDT, seeks to transform assessment from a judgmental tool into a supportive process that cultivates learners' intrinsic motivation. This transformation is essential in physical sciences, a subject often perceived as difficult or intimidating, where negative attitudes can hinder learning and persistence. Through intentionally designing formative assessments that address learners' psychological needs, the study aligns with SDT's premise that motivation quality, rather than quantity, is critical for sustained engagement and positive attitudes. When learners are motivated intrinsically, they engage more deeply, persist through challenges, and develop a more positive orientation toward physical sciences.

METHODOLOGY

Research Design

This study employed a descriptive research design and used a survey method to gather data, incorporating both pre- and post-questionnaires, assessing learners' attitudes towards physical sciences.

Targeted Population and Sampling Procedure

The study involved grade 10 physical science learners from five secondary schools located in the UMkhanyakude District. A total of 175 learners participated in this study and were divided into two groups: 118 learners in the experimental group and 57 in the control group. **Table 1** provides a detailed breakdown of how participants were distributed between the experimental and control groups across the five schools. The schools were purposively sampled. For each school, **Table 1** shows the number of learners assigned to the experimental group along with the percentage they represent out of the total experimental group. Similarly, it presents the number of learners in the control group and their corresponding percentage of the total control group.

For example, school A had 26 learners in the experimental group, representing 22.0% of that group, and another 18 learners in the control group, making up 10.3% of that group. This pattern is repeated for each of the five schools to provide a clear and comprehensive view of how participants were distributed. The totals at the bottom and far right of **Table 1** summarizes the overall number and percentage of learners in both the experimental and control groups across all schools.

Table 1. Number of learners by school, by group, and their percentages

School	Experimental		Control		Total	
	n	%	n	%	n	%
A	26	22.0			26	14.9
B	40	33.9			40	22.9
C	52	44.1			52	29.8
D			18	31.6	18	10.3
E			39	68.4	39	22.9
Total	118	100	57	100	175	100

Formative Assessment Intervention Strategies Took Place in the Experimental Group

Since this study aims to examine the impact of an intervention on improving learners' attitudes (ATT) within the experimental group, it is important to explore the details of the formative assessment interventions applied to this group, as well as the conditions maintained in the control group. The formative assessment interventions or treatment procedures were based on the framework proposed by Ozan and Kincal (2018), with modifications made by the researchers to align with the specific context of the study. The intervention instructions were developed around the four key formative assessment strategies outlined by Ozan and Kincal (2018), as presented in **Table 2**.

Experimental Group Teachers' Training and Guidance on Integrating the Intervention

To ensure the effective implementation of the formative assessment intervention, a one-day training session was conducted for the three grade 10 physical sciences teachers from schools A, B, and C, who were involved in teaching and learning to the experimental group. This training aimed to familiarize teachers with the core principles and practical applications of formative assessment strategies, including the use of questioning techniques, sharing clear learning objectives and success criteria, engaging effective and quality dialogue, peer and self-assessment, feedback loops, and learner reflection. The session was interactive and hands-on, allowing teachers to engage with sample lesson plans, discuss potential classroom challenges, and collaboratively design formative assessment activities aligned with the curriculum (CAPS).

During the training, emphasis was placed on how formative assessment could be seamlessly embedded into daily teaching practices rather than viewed as an additional task. Teachers were guided on how to create an inclusive classroom environment that encourages learner participation and self-directed learning. They were also provided with practical tools, which were checklists and rubrics, to monitor learners' progress. Support materials, including an intervention guide and sample formative assessment tasks, were distributed to assist teachers throughout the implementation period. This foundational training aimed to build teacher confidence and competence in using formative assessment to promote both academic improvement and positive learner attitudes toward physical sciences.

Table 2. Practices of formative assessment intervention in experimental group vs traditional method in control group

Formative assessment intervention strategies	Practices in the experimental group	Practices in the control group
Physical sciences grade 10 content, CAPS: Electricity and magnetism (3-week content)		
Physical sciences teacher's activity prior to the lesson		
Explanation and clarification of learning objectives and success criteria	• Explanation of daily lesson objectives was clearly stated during the 3-week content • Teachers constantly remind learners of the success criteria	• No explanation was given to learners; instead, prior to the lesson, teachers were seeking prior knowledge from learners • No success criteria integrated
Physical sciences teacher's activity during the lesson		
Engineering effective and quality dialogue and inquiry	• Quality dialogue was enhanced through the formation of heterogeneous groups • The nature of questions incorporated was pitched at higher cognitive levels, hence dialogue and inquiry were enhanced	• The formation of groups was upon learners' choice, therefore, heterogenous was overlooked by teachers • The nature of the question did not consider the cognitive level higher higher-order thinking
Providing feedback that moves learners forward (feedforward)	• Detailed feedback was provided to learners in a commentary form, not scores • Ample opportunities were provided to learners to engage with feedback, however, the teaching and learning time was considered • Instructional and lesson delivery was adjusted based on learners' feedback to teachers	• Feedback in terms of scores was dominated • Opportunities to engage with feedback were slim because the nature of the feedback did not detail what learners needed to consider • Instructional and lesson delivery was more teacher-centered, the reason identified, teachers were rushing to cover the lesson content
Physical sciences teacher's activity during and after the lesson		
Using self and peer assessment	• Self and peer assessment were integrated for the whole duration of 3 weeks • Learners were instructed on procedures for conducting peer and self-assessment • A rubric to assess self and peer assessment was discussed in detail with learners before embarking on the assessment	• Self and peer assessment were integrated unintentionally • No clear explanation on the procedures for conducting self and peer assessment was provided to learners

Research Tool Used

Al-Tarawneh (2023) indicated the value of translating study objectives into a set of data needs, which in turn shape the research questions aimed at collecting pertinent information and subsequently transforming research questions into questionnaires. In this study, data collection occurred through the administration of questionnaires as a pre- and post-test to evaluate learners' attitudes and utilizing the attitudes scales (ATT) devised by Çermik and Kara (2020). The questionnaires were moderated and validated by physical sciences subject specialists, including a subject advisor and a senior teacher. There were 22 items, and the questions comprised predominantly positive and negative statements organized into constructs: unwillingness, interest, necessity, and academic self (see **Appendix A**). To ensure face and content validity, the questionnaires were presented to experts for feedback. Following their opinions, some items were rephrased, reversed and edited, with no items removed. Subsequently, after the complete development of the tool, pilot testing was conducted in one school, which was not part of the study. The pilot testing affirmed the reliability of learners' questionnaires.

The Initial Theoretical Model for Attitudes was Devised from Çermik and Kara (2020)

The overview of the model to be examined consists of four dimensions: interest with six items, unwillingness with six items, academic self with five items, and necessity with five items. This theoretical model was intended to gauge learners' attitudes towards physical sciences. In **Figure 2**, ATT stands for attitude. Also, some items like ATT 16, 17 and 22 have R in brackets, which means the R means a reversed statement from its original form.

These links demonstrate the dynamic interplay between interest, unwillingness, academic self, and necessity in shaping individuals' attitudes and behaviors towards academic tasks and learning activities. Understanding these relationships informs interventions and strategies aimed at promoting positive attitudes and motivation in the physical sciences context.

Data Analysis

The data was analyzed using statistical package for social sciences version 26, while the graphs and tables were produced using Microsoft Excel 2021. The 2-way

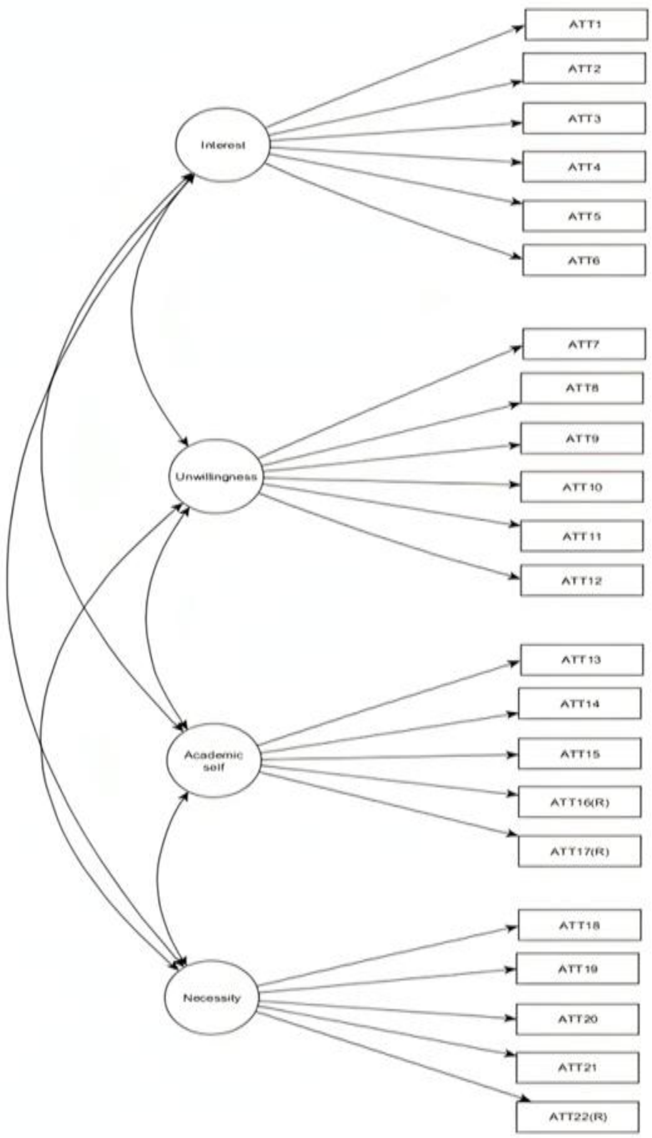

Figure 2. Theoretical measurement model for attitudes (Source: Authors' own elaboration)

ANOVA was employed as a statistical approach with repeated measures based on the intention to ensure a high level of confidence in the results.

Exploratory Factor Analysis

To explore an alternative grouping of items into factors different from the initially proposed theoretical model (**Figure 2**), an exploratory factor analysis (EFA) was conducted. The EFA model utilized principal components extraction and oblimin rotation. Diagnostic statistics indicated the appropriateness of proceeding with the factor analysis, with the Kaiser-Meyer-Olkin measure of sampling adequacy reaching 0.767 and Bartlett's test of sphericity yielding a statistically significant chi-square of 1,064.255 for 231 degrees of freedom.

The initial EFA revealed four factors, as appears in **Figure 2**. However, a second EFA was performed based on the interpretation of item grouping, factor loadings, and examination of internal consistency results. In this iteration, items ATT1, ATT3, ATT15, and ATT17 were excluded, and reversed items ATT16 and ATT22 were included in their unreversed state.

The second EFA model resulted in a Kaiser-Meyer-Olkin measure of sampling adequacy of 0.791, and Bartlett's test of sphericity yielded a statistically significant chi-square of 797.835 for 153 degrees of freedom. This second EFA identified five factors with eigenvalues exceeding 1. Together, these factors explained 56.039% of the variation, with the first factor contributing 26.209%, the second contributing 11.230%, the third contributing 6.663%, the fourth contributing 6.156%, and the fifth contributing 5.782%. The pattern matrix, illustrating the grouping of items by factor along with their respective factor loadings, is presented in **Table 3**.

Table 3. EFA patten matrix for attitude statements (5 grouping)

ATT	1	2	3	4	5
ATT7 I see physical sciences as a waste of time.	0.911	-0.002	-0.056	-0.179	-0.065
ATT9 I am very bored during physical sciences classes.	0.745	-0.085	-0.122	0.015	-0.133
ATT8 I do not want to go to school on the days physical sciences is taught.	0.644	-0.099	0.019	0.034	-0.111
ATT11 I would not attend physical sciences subject if I had a choice not to.	0.562	0.172	0.188	0.233	0.009
ATT22 I do not think physical sciences will be useful for me after I have completed high school.	0.555	-0.162	0.050	-0.024	0.001
ATT10 It is a torture for me to study for physical sciences.	0.524	0.120	0.104	0.234	0.076
ATT14 I do not believe I could be successful however much I study for physical sciences.	0.522	-0.062	0.051	0.140	0.516
ATT4 I enjoy conducting in-depth research on what I learn in physical sciences.	0.032	0.811	0.046	-0.110	-0.081
ATT2 I enjoy daily repetition of what I learn in physical sciences classes.	-0.034	0.628	-0.067	0.061	0.215
ATT16 I see myself as a successful learner in physical sciences.	-0.215	0.625	0.018	-0.045	0.077
ATT20 I believe what I learnt in physical sciences makes my daily life easier.	0.000	0.396	-0.318	-0.217	0.028
ATT19 I believe our education would be lacking if there were no physical science subject in the high school curricula	0.052	-0.131	-0.846	-0.041	0.151
ATT18 I believe physical sciences is an important subject that needs to be learnt by everyone.	-0.014	0.045	-0.779	0.056	-0.048
ATT21 Physical sciences is necessary for me to have a good occupation.	-0.054	0.405	-0.487	0.166	-0.056

Table 3 (Continued). EFA patten matrix for attitude statements (5 grouping)

ATT	1	2	3	4	5
ATT13 Physical sciences is not a subject I can learn by my own effort without receiving special support.	-0.121	-0.200	-0.057	0.842	-0.014
ATT12 I feel very nervous during physical sciences classes.	0.187	0.100	0.008	0.692	-0.072
ATT6 What I learn in physical sciences excites me.	-0.136	0.123	-0.111	0.038	0.695
ATT5 Topics of physical sciences attract my interest.	-0.118	0.009	-0.027	-0.166	0.612

Table 4. Pre- and post-intervention mean and standard deviation

Variable	Group	Pre	Pre	Post	Post
		Mean	Standard deviation	Mean	Standard deviation
Attitude 1. Unwillingness	Experimental	2.071	0.894	1.602	0.346
	Control	1.952	0.566	1.920	0.365
Attitude 2. Interest 1	Experimental	3.737	0.730	4.146	0.454
	Control	3.733	0.646	3.561	0.539
Attitude 3. Necessity	Experimental	3.622	0.975	4.627	0.393
	Control	3.743	0.696	3.702	0.576
Attitude 4. Needs support	Experimental	2.915	1.123	2.331	0.425
	Control	2.816	0.957	2.693	0.800
Attitude 5. Interest 2	Experimental	3.653	0.849	4.534	0.479
	Control	3.579	0.772	3.667	0.650

Table 5. Interaction effect statistics for attitude indicators for the experimental group

	Pillai's trace	F	df1	df2	p	Eta squared	Effect size
Unwillingness	0.105	20.276	1	173	0.000	0.105	Large
Interest 1	0.225	50.140	1	173	0.000	0.225	Large
Necessity	0.294	72.181	1	173	0.000	0.294	Large
Needs support	0.062	11.415	1	173	0.001	0.062	Medium
Interest 2	0.228	51.135	1	173	0.000	0.228	Large

Items ATT7, ATT9, ATT8, ATT11, ATT22, ATT10, and ATT14, constituting the first factor, were designated as "*unwillingness*." Items ATT4, ATT2, ATT16, and ATT20, forming the second factor, were denoted as "*interest 1*." Items ATT19, ATT18, and ATT21, comprising the third factor, were labelled "*necessity*." Items ATT12 and ATT13, shaping the fourth factor, were identified as "*needs support*," while items ATT6 and ATT5, constituting the fifth factor, were termed "*Interest 2*." It must be noted that other factors, such as the need for support and interest 2, had two items after EFA; some items were removed due to their low internal consistency. The EFA produced two Interest factors, hence interest 1 is about the enjoyment of learning physical sciences, while interest 2 is about the excitement of learning physical sciences.

The Cronbach's alpha internal consistency measures for the empirical factors one through five were 0.794, 0.662, 0.634, 0.503, and 0.449, respectively. It is important to note that while some of the reliability coefficients may appear low, factor four and factor five are composed of only two items each, and these items can be conceptually related.

RESULTS AND FINDINGS

Table 4 provides the mean and standard deviation values before and after the intervention for the measures derived earlier. These mean values were employed in a mixed between-within ANOVA to examine whether noteworthy alterations in the measures are due to the formative assessment intervention. Overall, the data suggest that the intervention has had a positive impact on learners' attitudes towards physical sciences.

Table 5 presents results from a multivariate analysis using Pillai's trace, showing that the intervention significantly affects attitudes of learners towards physical sciences. Each variable, such as unwillingness, interest 1, and necessity, has a very low p-value, indicating strong statistical significance. Additionally, the Eta squared values ranging from medium (≥ 0.05) to very large (≥ 0.25) demonstrate that the intervention's effects are not only statistically significant but also practically meaningful. This combination of low p-values and substantial effect sizes confirms the intervention's significant and impactful influence across the measured outcomes.

In the context of this study, quantitative data analysis, where we as researchers analyzed interaction effects in statistical tests, the terms **df**, **p**, **eta squared**, and **effect size** were deemed very important for interpreting results. Here's what each term means as abbreviated in **Table 5**:

1. **df (degrees of freedom)**

df1 and **df2** refer to the degrees of freedom associated with the test statistics.

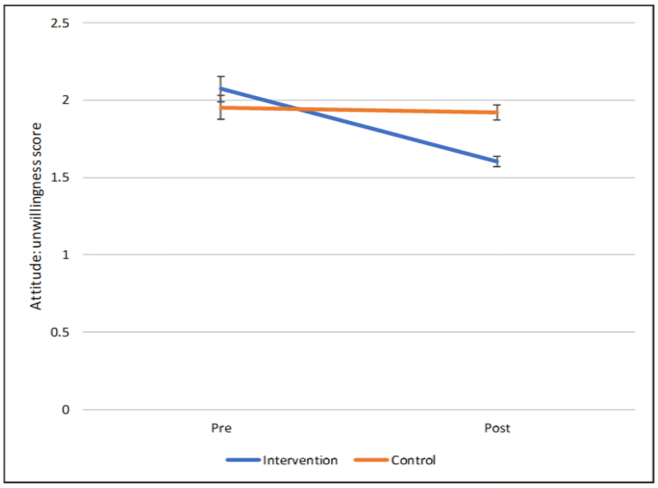

Figure 3. Pre- and post-attitude: unwillingness rating for intervention and control groups (Source: Authors' own elaboration)

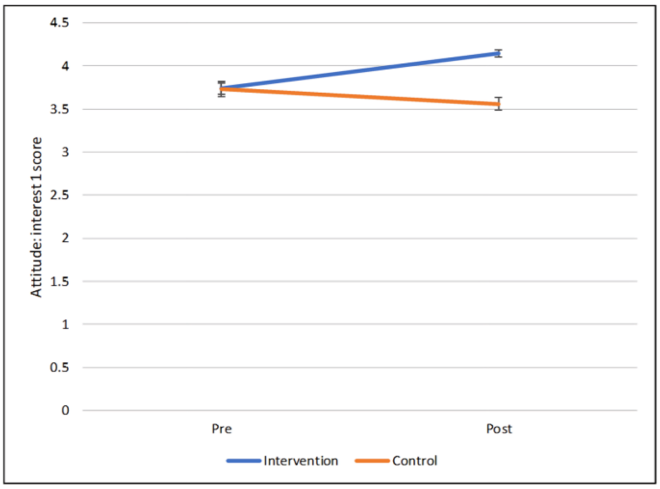

Figure 4. Pre- and post-attitude: interest 1 rating for intervention and control groups (Source: Authors' own elaboration)

df1: Corresponds to the number of groups in the factors being tested.

df2: Related to the sample size and helps determine the variability expected by chance.

2. **p (p-value)**

The p-value indicates the probability of observing the data, or something more extreme, to determine if the null hypothesis is true.

A low p-value (typically < 0.05) suggests that the observed effect is statistically significant, and it's unlikely to have occurred by chance. A high p-value (greater than 0.05) suggests there is not enough evidence to reject the null hypothesis.

3. **Eta squared**

A measure of effect size that indicates how much of the variance in the dependent variable is explained by the independent variable(s). Ranges from 0 to 1: 0= no effect, 1 = perfect effect

4. **Effect size**

In the context of this study, the magnitudes of the relationship in the data are presented as a factor.

ANALYSIS OF EACH ATTITUDE FACTOR BASED ON THE SECOND EFA (PRE- AND POST-INTERVENTION)

Unwillingness

A mixed between-within ANOVA was conducted to assess the impact of formative assessment over time (pre- and post-intervention) on unwillingness scores. **Table 5** shows a significant interaction effect. As illustrated in **Figure 3**, both groups had similar unwillingness scores before the intervention. After the intervention, scores remained unchanged in the control group but decreased in the intervention group, indicating that formative assessment reduces unwillingness. This change pattern difference between groups reflects a large effect size, as reported in **Table 5**.

Interest 1 (Enjoyment)

The mixed between-within ANOVA revealed a significant interaction effect for interest 1, as shown in **Table 5**. **Figure 4** presents the mean Interest 1 scores with standard errors for both the experimental and control groups before and after the intervention. Initially, both groups had similar scores. Post-intervention, the control group's scores declined, while the intervention group's scores increased, indicating that formative assessment enhances Interest 1. The differing change patterns between the groups reflect a large effect size, as reported in **Table 5**.

Necessity

The mixed between-within ANOVA revealed a significant interaction effect for necessity, as shown in **Table 5**. **Figure 5** displays the mean necessity scores with standard errors for both the intervention and control groups before and after the intervention. Initially, both groups had similar scores. After the intervention, the control group's scores remained stable, while the intervention group showed an increase, indicating that formative assessment enhances perceived necessity. This difference in score changes between groups reflects a large effect size, as noted in **Table 5**.

Need Support

The mixed between-within ANOVA revealed a significant interaction effect for needs support, as shown in **Table 5**. **Figure 6** presents the mean needs support scores with standard errors for both the intervention and control groups before and after the intervention. At the pre-measurement stage, both groups had similar scores. Post-intervention, the control group's scores remained

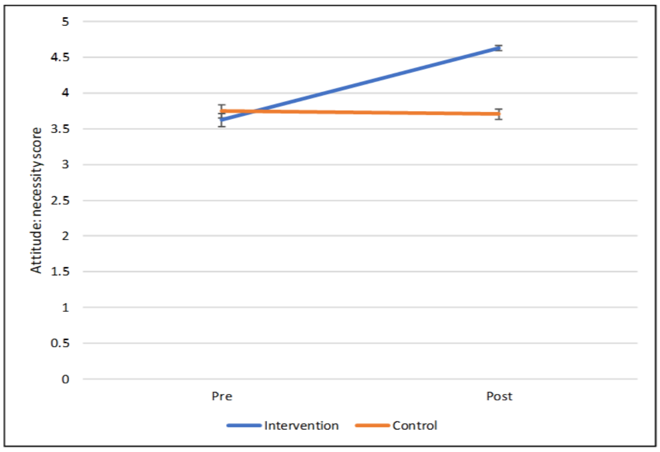

Figure 5. Pre- and post-attitude: necessity rating for intervention and control groups (Source: Authors' own elaboration)

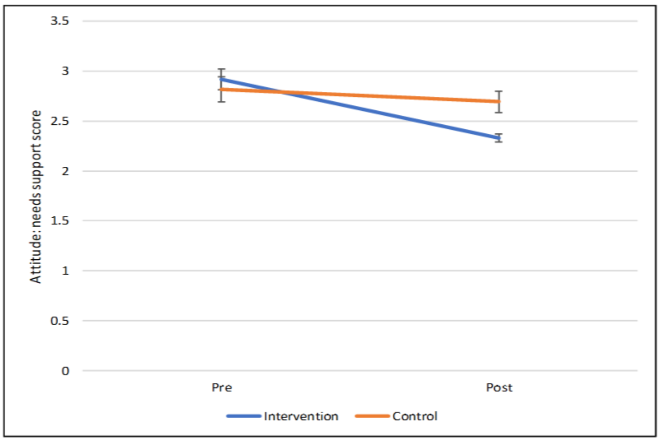

Figure 6. Pre- and post-attitude needs support rating for intervention and control groups (Source: Authors' own elaboration)

unchanged, while the intervention group's scores decreased, suggesting that formative assessment reduces the need for support. This differing pattern of change between groups reflects a medium effect size, as indicated in **Table 5**.

Interest 2 (Excitement)

The mixed between-within ANOVA revealed a significant interaction effect for interest 2, as shown in **Table 5**. **Figure 7** illustrates the mean interest 2 scores with standard errors for both the intervention and control groups before and after the intervention. At the pre-measurement stage, scores were identical across groups. After the intervention, scores increased in the intervention group but remained unchanged in the control group, suggesting that formative assessment enhances interest 2. This change pattern between groups reflects a large effect size, as indicated in **Table 5**.

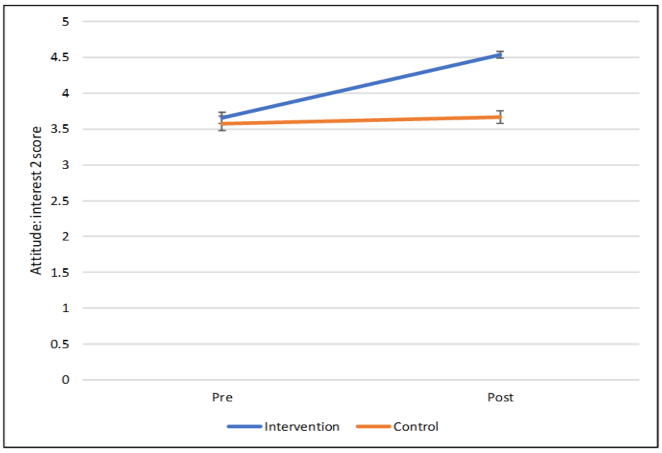

Figure 7. Pre- and post-attitude: interest 2 rating for intervention and control groups (Source: Authors' own elaboration)

DISCUSSION OF FINDINGS

The findings from the mixed between-within ANOVA analyses indicate that exposure to formative assessment has a significant and meaningful impact on several key attitudinal factors: unwillingness, interest (interest 1 and interest 2), necessity, and need for support. These results are in line with a growing body of educational research highlighting the role of formative assessment in promoting learners' motivation, engagement, and self-directed learning, as noted by Mohamad Nasri et al. (2022).

The significant decrease in unwillingness scores among learners in the intervention group suggests that formative assessment practices may help reduce resistance to learning. Khatter et al. (2024) argue that when learners receive clear learning goals, constructive feedback, and opportunities to participate actively in their learning, they are more likely to feel empowered and less likely to exhibit reluctance or disengagement. Formative assessment provides a structured framework that reduces uncertainty, encourages learners' reflection, and offers a sense of control over learning, all of which contribute to lowering negative attitudes such as unwillingness.

Similarly, the positive shifts in interest scores, particularly interest 1 (enjoyment in this study context) and interest 2 (excitement in this study context), support the argument of Aust et al. (2024) that formative assessment can enhance learners' intrinsic motivation. Interest 1 increased post-intervention in the experimental group while declining in the control group, and interest 2 also showed a marked rise, indicating growing enthusiasm and engagement. These trends are consistent with SDT (Ryan & Deci, 2000), which posits that learning environments that support autonomy, competence, and relatedness tend to foster deeper interest and motivation. Formative assessment aligns well with these principles, as it encourages learners to set goals, assess their progress, and see tangible improvements over time, which can increase their engagement and interest in the subject matter.

The observed increase in necessity scores among the experimental group further supports the value of formative assessment in shaping learners' perceptions of learning relevance. When learners understand the purpose behind tasks and receive feedback that links their efforts to outcomes, they are more likely to perceive the learning activities as essential. Zou et al. (2024) note that effective formative assessment helps clarify expectations and aligns learning tasks with learners' goals, thereby increasing the perceived necessity of academic work. This, in turn, can enhance learners' commitment and persistence.

A particularly noteworthy finding is the decrease in need support scores for the experimental group. While it might initially seem counterintuitive, this result likely reflects a shift toward greater learners' autonomy and self-regulation. As learners engage more deeply with formative assessment practices such as setting personal goals, engaging in peer or self-assessment, and acting on feedback, they may become less dependent on teacher support. According to Heritage (2021), these are key components of self-regulated learning, where learners develop the capacity to manage their own educational progress, thus requiring less external assistance.

Together, these findings present a compelling case for the implementation of formative assessment as a means to improve learners' attitudes and engagement. The consistent pattern across all five attitudinal factors reductions in unwillingness and need for support and increases in interest and perceived necessity suggests that formative assessment not only supports academic performance but also cultivates a more positive and autonomous learning mindset. By enhancing clarity, promoting learners' agency, and offering meaningful feedback, formative assessment helps create an environment where learners are more motivated, more engaged, and more capable of directing their own learning. These outcomes align closely with both theoretical frameworks and empirical studies in the field, reinforcing the importance of integrating formative assessment into the teaching and learning of physical sciences.

DISCUSSION IN RELATION TO THEORETICAL FRAMEWORK (SELF-DETERMINATION THEORY)

The findings of this study also align closely with SDT, a well-established motivational framework developed by Deci and Ryan (2000), which emphasizes the role of three basic psychological needs: autonomy, competence, and relatedness in fostering intrinsic motivation and optimal learning. The observed changes in attitudes, such as reduced unwillingness and need for support, along with increased interest and perceived necessity, can be effectively interpreted through this lens.

Formative assessment supports autonomy by involving learners in the learning process through practices like self-assessment, goal setting, and feedback that encourages personal growth rather than external judgment. In this study, the experimental group showed decreased unwillingness and reduced dependence on external support, suggesting that learners felt more in control of their learning. When learners feel that they have choice and ownership, they are more likely to engage willingly and persist in the face of challenges.

The competence need is addressed when learners perceive that they are capable of achieving success and improving their skills. Formative assessment contributes to this by providing specific, timely, and constructive feedback that helps them identify both strengths and areas for development. The increase in both interest 1 and interest 2 among the experimental group indicates that learners not only found learning more engaging but also likely felt more capable and confident, a direct reflection of enhanced perceived competence.

Relatedness, the third core need in SDT, refers to feeling connected and supported within a learning environment. While this study does not directly measure relatedness, the overall positive changes in attitudes, especially the increase in perceived necessity, imply that learners may have felt a stronger sense of purpose and connection to their learning community. Formative assessment often involves collaborative elements such as peer feedback, discussion, and shared reflection, all of which can enhance social bonds and a sense of belonging.

RECOMMENDATIONS AND CONCLUSION

Based on the findings of this study, which demonstrate the significant and meaningful impact of formative assessment on learners' attitudes, including reductions in unwillingness and need for support, and increases in interest and perceived necessity, a number of actionable recommendations can be made for teachers, policymakers, and researchers.

First, teachers should be encouraged and trained to incorporate formative assessment as a regular and deliberate part of instructional practice. This includes not only providing feedback on learners' work but also doing so in a way that is constructive, timely, and specific. Feedback should clearly communicate learning goals, identify areas for improvement, and offer strategies for progression. Glassey and Bälter (2020) emphasize that the effectiveness of feedback depends not just on its presence, but on its quality. To maximize its benefits, feedback should guide learners on where they are going, how they are going, and where to go next.

Schools and district officials should provide professional development opportunities focused on formative assessment strategies. Teachers must be equipped with the skills and confidence to implement diverse methods such as peer-assessment, self-assessment, and formative questioning (Devaki, 2024). These practices promote learner autonomy, a factor strongly associated with increased motivation and reduced need for external support. Given that the study found a decrease in the need for support following the intervention, supporting teacher competence in fostering learners' independence is crucial.

Policymakers should also recognize the value of formative assessment and ensure it is integrated into curriculum frameworks and assessment policies. Too often, educational policies emphasize summative assessments at the expense of ongoing, developmental feedback. Through the rebalancing of assessment policies to value formative practices, educational systems can support deeper, more meaningful learning. Furthermore, evaluation standards should reflect not just learning outcomes, but also improvements in learner attitudes and motivation, as these are essential to long-term educational success.

In the classroom, it is essential that formative assessment practices are inclusive and learner-centered. Teachers should strive to create a supportive environment where learners feel safe to make mistakes, ask questions, and take intellectual risks. This kind of climate, underpinned by formative assessment, helps reduce unwillingness and encourages engagement. Learners should be involved in the assessment process, given opportunities to reflect on their learning, and encouraged to take ownership of their progress. As Tani et al. (2021) argue, learners' engagement in assessment is key to driving motivation and achievement.

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APPENDIX A

Attitudes

This section includes questions measuring your attitude toward physical science. Please read each statement and then choose the response option that best represents your attitude.

Please use a cross (X) to indicate your response.

Table A1. Questions measuring attitude toward physical science

Items	SD	D	SA	A	AA
1. I look forward to physical sciences classes.					
2. I enjoy daily repetition of what I learn in physical sciences classes.					
3. I am more willing to study for the physical sciences course than for another course.					
4. I enjoy conducting in-depth research on what I learn in physical sciences.					
5. Topics of physical sciences attract my interest.					
6. What I learn in physical sciences excites me.					
7. I see physical sciences as a waste of time.					
8. I do not want to go to school on the days physical sciences is taught.					
9. I am very bored during physical sciences classes.					
10. It is a torture for me to study for physical sciences.					
11. I would not attend physical sciences subject if I had a choice not to.					
12. I feel very nervous during physical sciences classes.					
13. Physical sciences is not a subject I can learn by my own effort without receiving special support.					
14. I do not believe I could be successful however much I study for physical sciences.					
15. I believe it is a miracle for me to understand the topics of physical sciences.					
16. I see myself as a successful learner in physical sciences.					
17. Physical sciences is among the courses I can learn easily.					
18. I believe physical sciences is an important subject that needs to be learnt by everyone.					
19. I believe our education would be lacking if there were no physical sciences subject in the high school curricula.					
20. I believe what I learnt in physical sciences makes my daily life easier.					
21. Physical sciences is necessary for me to have a good occupation.					
22. I do not think physical sciences will be useful for me after I have completed high school.					

Note. SD: Strongly disagree; D: Disagree ; SA: Somehow agree; A: Agree; & AA: Absolutely agree